Linking the economic costs and water quality benefits of conservation in agricultural lands: an Iowa assessment

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Presentation Overview

- Background on USEPA Clean Watersheds Needs Survey (2000)
- Brief overview of Iowa Agriculture
- Describe modeling framework
  - SWAT calibration / validation
  - conservation practice algorithm / scenarios
- SWAT assumptions & results
- Cost assumptions & results
- Conclusions & USEPA reaction

USEPA Clean Watersheds Needs Survey (CWNS)

- Conducted about every four years
  - required under section 516 of the Clean Water Act
- Document needs eligible for Clean Water State Revolving Fund (CWSRF)
- 2000 “documented needs”: ~$181 billion
  - waste treatment plants, etc.: $167 billion
  - diffuse sources: $14 billion
    - **agricultural cropland: $0.5 billion**

USEPA CWNS

- Simulated national “gap estimates” for agricultural cropland
- Total U.S. estimate: $4.4 billion

  - buffers, nutrient management, conservation tillage, and CRP
  - acknowledge other practices may be needed

Iowa Assessment

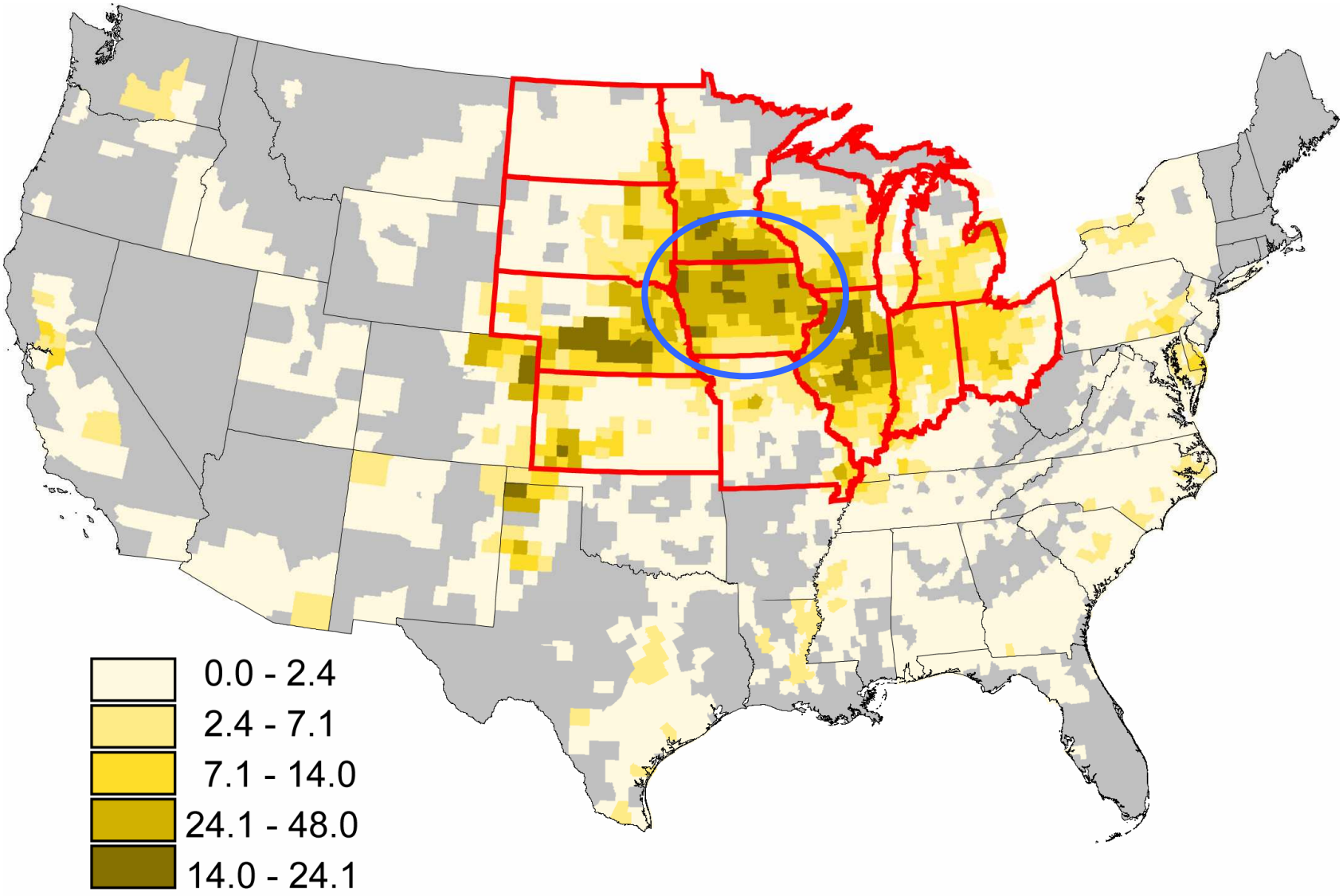
- Iowa Dept. of Natural Resources (IDNR)

  - requested statewide “nonpoint source pollution needs assessment”

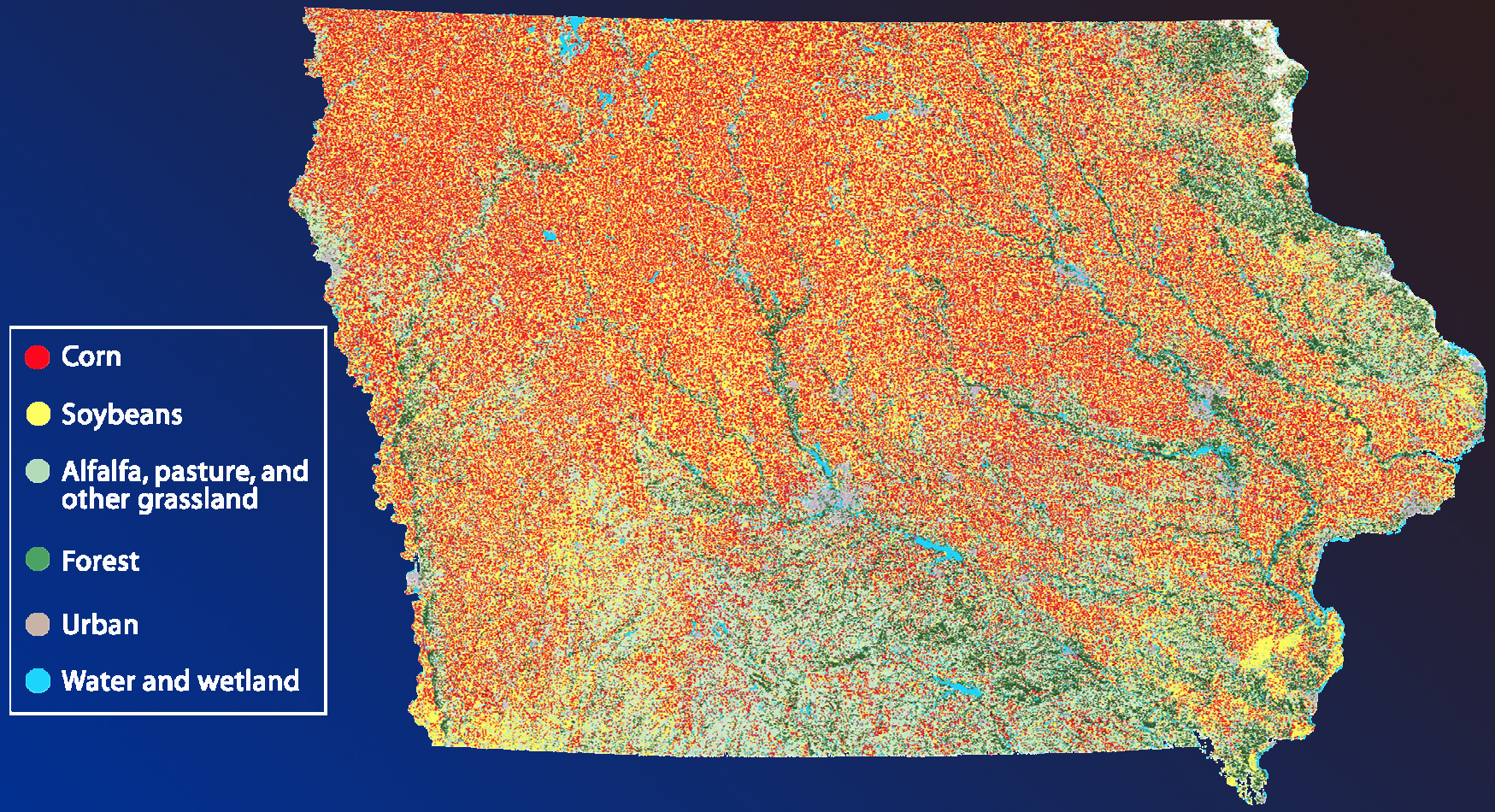
  - conviction: 2000 USEPA national cropland diffuse pollution estimates were way too low

  - goal: submit cropland diffuse pollution cost estimates to 2004 CWNS

U.S. corn production (million bushels) by county



2002 Iowa Landuse Map



Iowa Crop Production

- 2004 planted corn area = 5.14 (10^6) ha; harvested area = 5.02 (10^6) ha
  - $3.71 billion in total sales
- 2004 soybean area = 4.13 (10^6) ha; harvested area = 4.11 (10^6) ha
  - $2.60 billion in total sales

2003 Iowa Crop Rankings

Crop	Rank	% of U.S. Total
Corn (grain)	1	17
Corn (silage)	7	5
Soybeans	1	15
Oats	6	6
Winter Wheat	38	-
Alfalfa Hay & Mixtures	7	6
Total area of principal crops harvested	1	8

A lot of Nutrients

- Average nitrogen fertilizer application rate on corn =140-150 kg/ha
  - > 700 (10^6) kg annually
- Phosphorus fertilizer also applied to corn
- Also significant nitrogen and phosphorus input from livestock manure

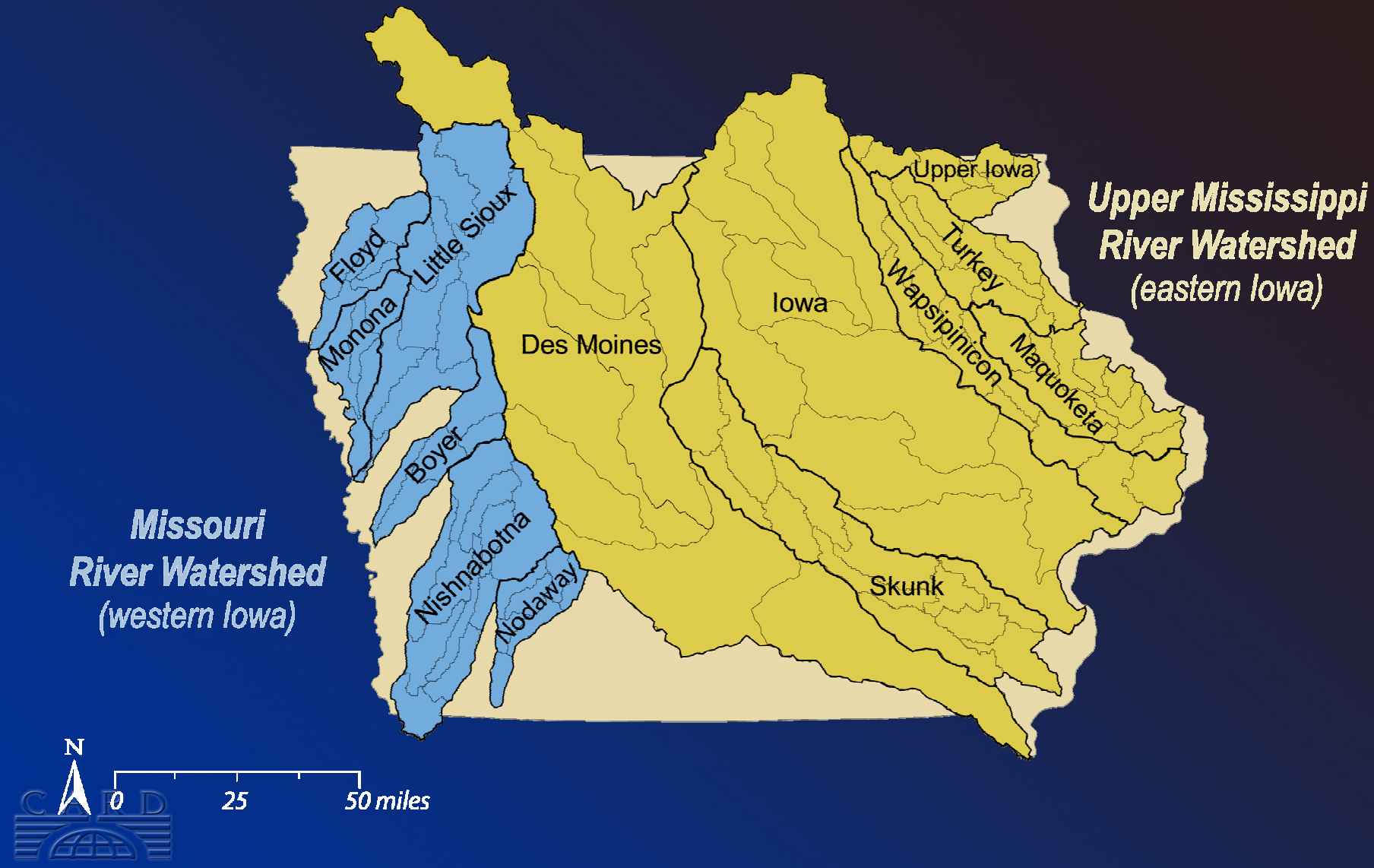
Simulation Framework

- SWAT model (environmental impacts)
- USDA 1997 National Resources Inventory (NRI) database & other data
- **Conservation practice algorithm / scenarios**
- Conservation practice cost data
- Discrete choice economic models

NRI Database and other Data

- National Resources Inventory (NRI)
  - USDA-NRCS national statistical survey (~800,000 “points”)
  - collected every 5 years between 1982-97 (used 1997 data)
  - comprehensive cropping history (rotations) and other landuse data
  - baseline conservation practices; soil types, other data
- Obtained tillage practice and other management data from other USDA surveys
- Climate and soil data from other sources

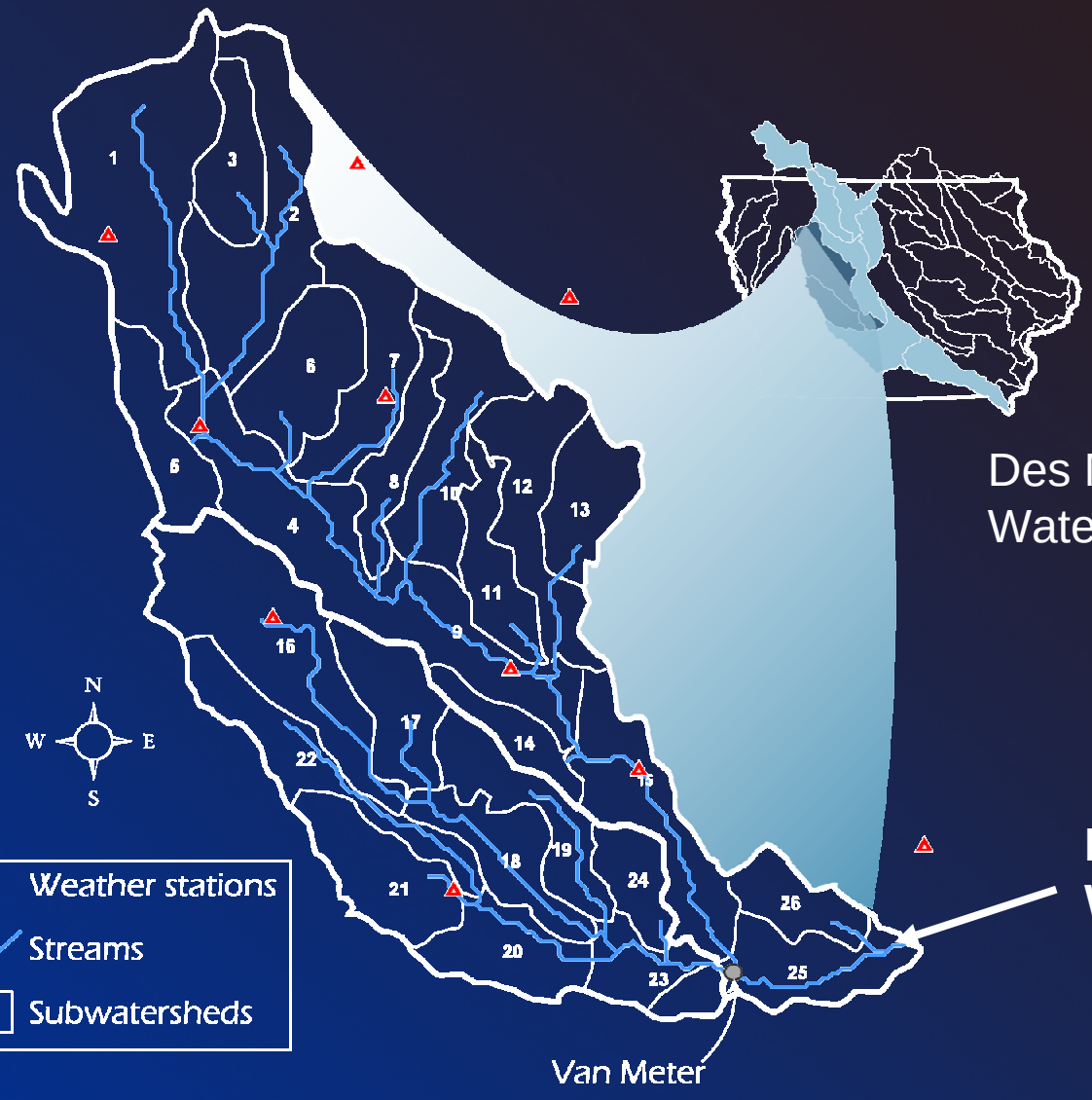
13 Watersheds Simulated in SWAT for IDNR Study (cover 87% of Iowa)



Watershed Characteristics

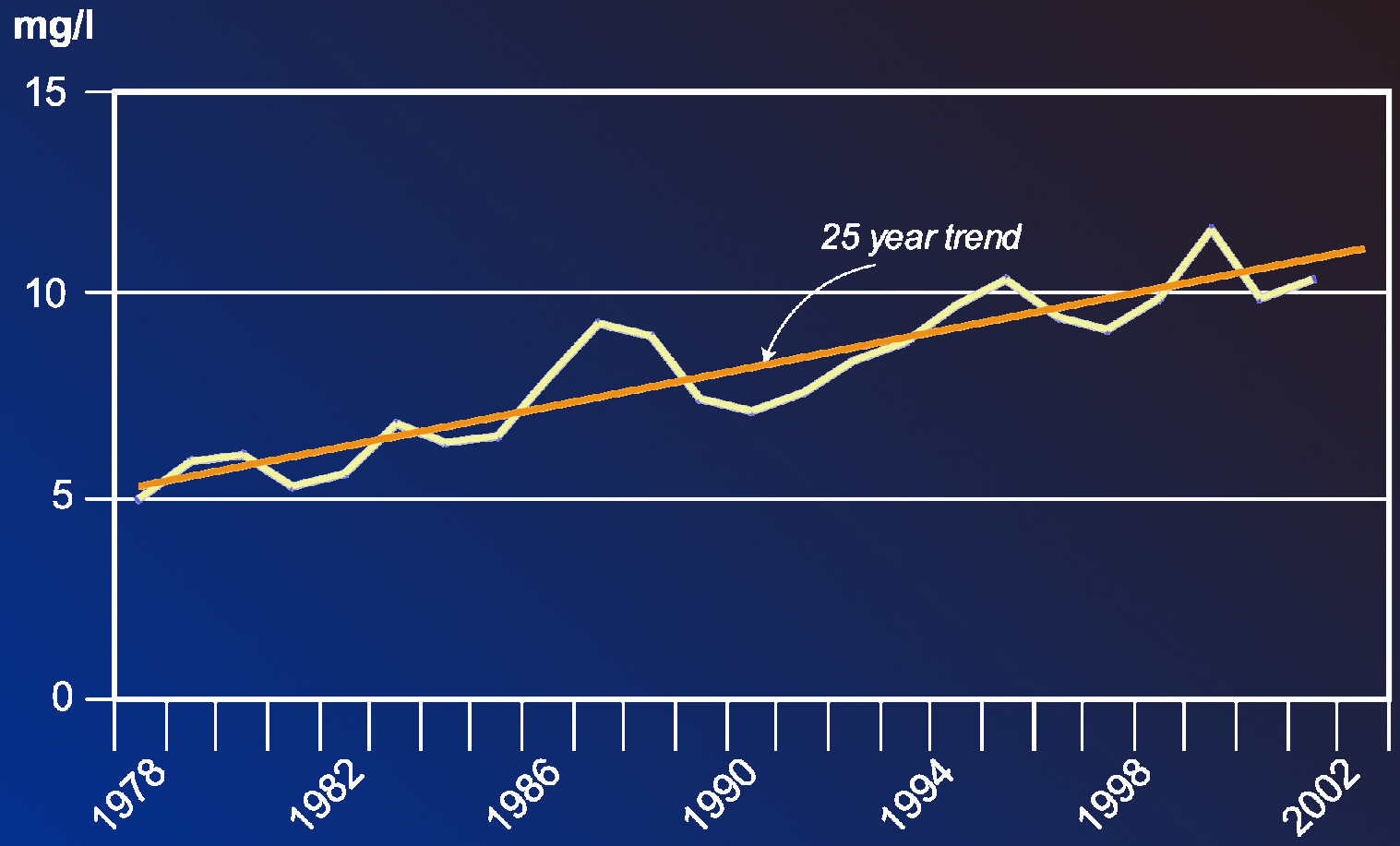
Watershed Name	# of NRI cropland points	Drainage area (km^2)	# of subwatersheds	Key Land Uses (%)	
				Cropland	Grassland
Floyd	373	2,376	5	84	13
Monona	231	2,452	5	78	19
Little Sioux	811	9,203	10	86	13
Boyer	298	2,820	5	68	26
Nishnabotna	766	7,718	11	84	15
Nodaway	186	2,051	7	52	41
Des Moines	2942	37,496	9	71	16
Skunk	1022	11,246	12	69	25
Iowa	3374	32,796	9	77	12
Wapsipinicon	789	6,582	11	77	19
Maquoketa	503	4,827	10	56	32
Turkey	410	4,400	9	56	25
Upper Iowa	164	2,569	7	51	26

Raccoon River Watershed
Calibration and Validation of SWAT



NO_3-N Concentrations in the Racoon River

(Five Year Running Average of May measurements)



Des Moines Water Works

- Raccoon River water is preferred source
- Supplies drinking water for 350,000 people

Nitrate Removal Facility

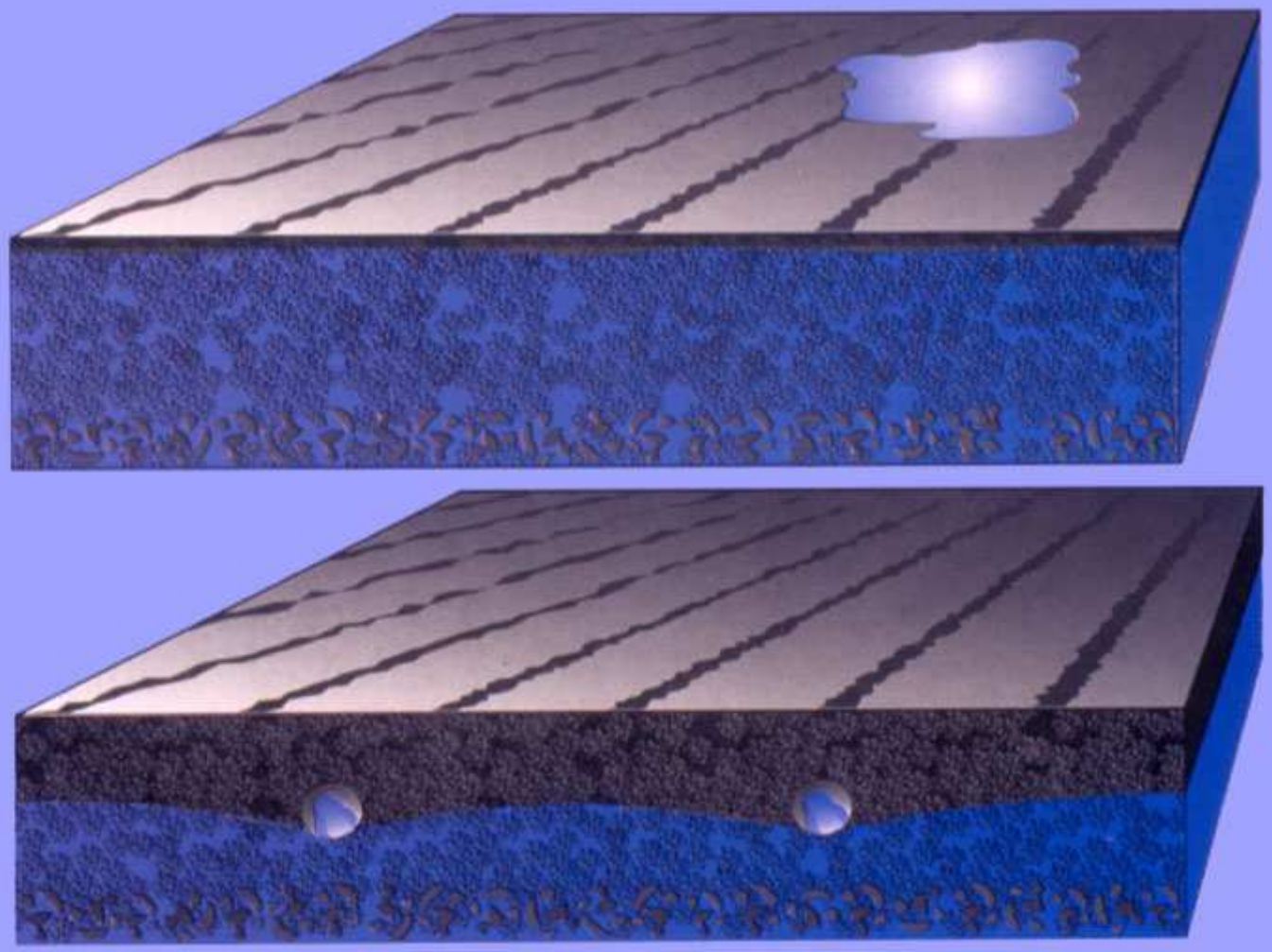
- On average, MCL for Nitrate is exceeded 100 days per year.
- Operating removal facility increases cost of water treatment.

SWAT Calibration/Validation

- **Manual calibration (baseline – NRI data)**
  - streamflow, sediment, and nitrate
  - calibration period: 1981-89
  - validation period: 1990-2000 for flow and nitrate; 1990-94 for sediment

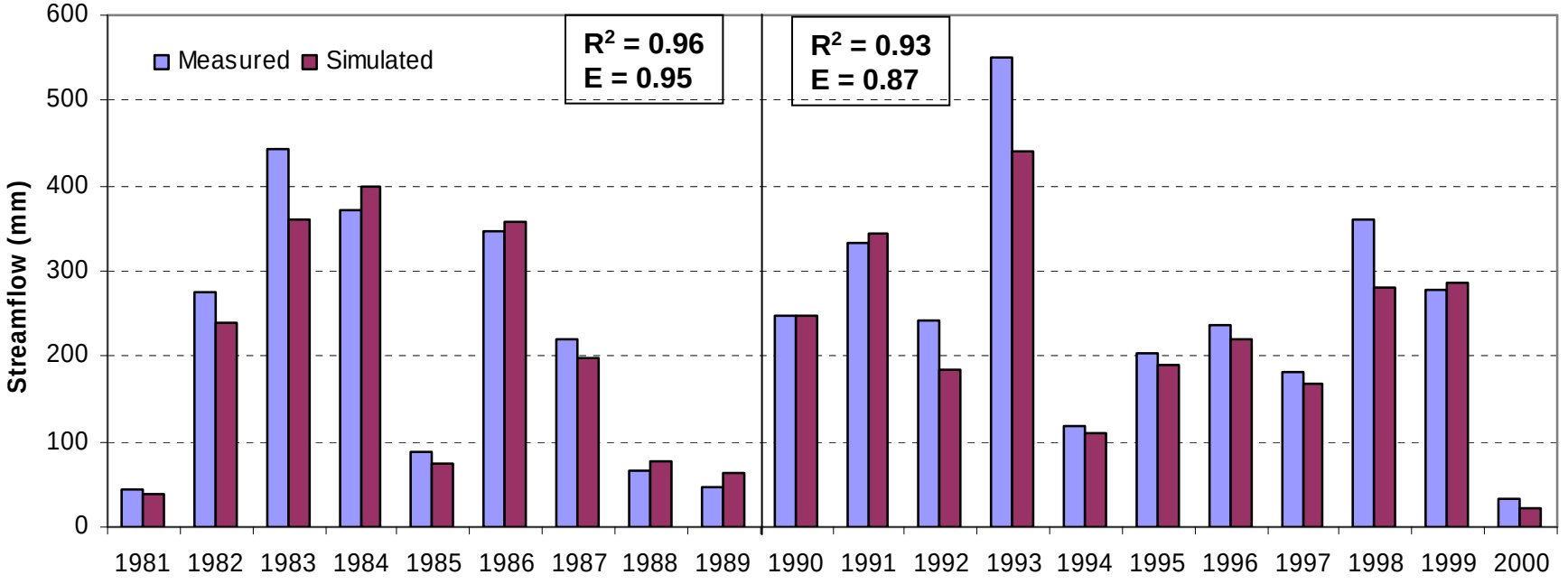
- **Streamflow calibration and validation were also performed for each of the 13 study watersheds (not shown)**

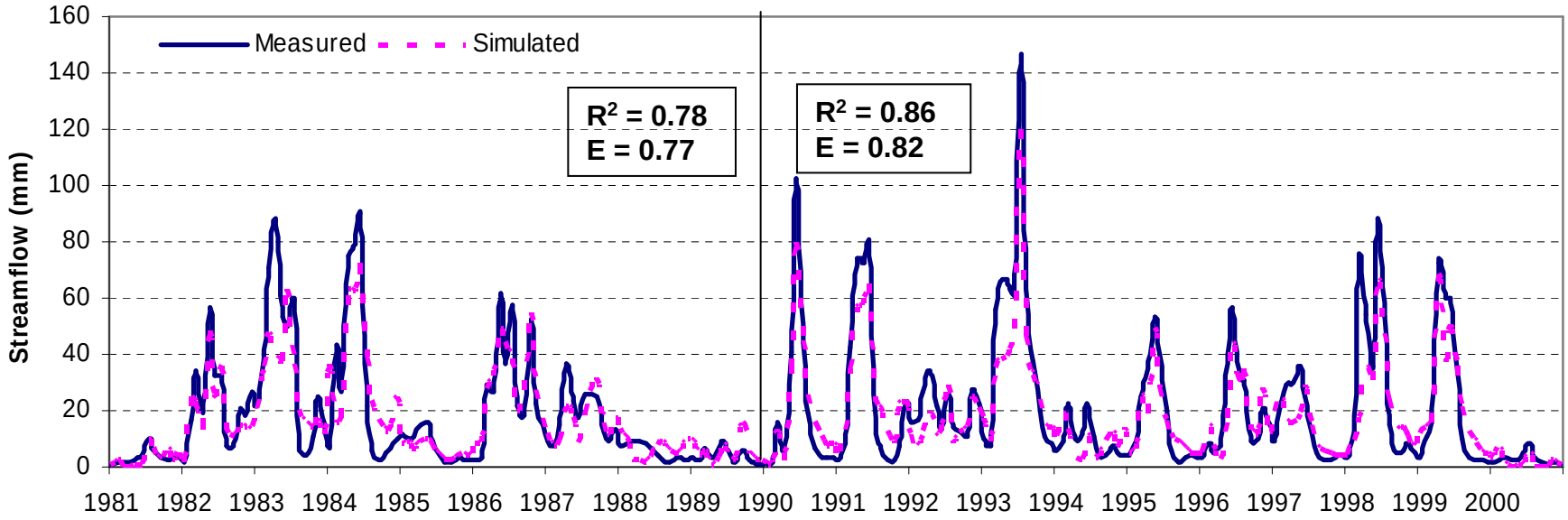
Effects of Tile Drainage on Soil Water



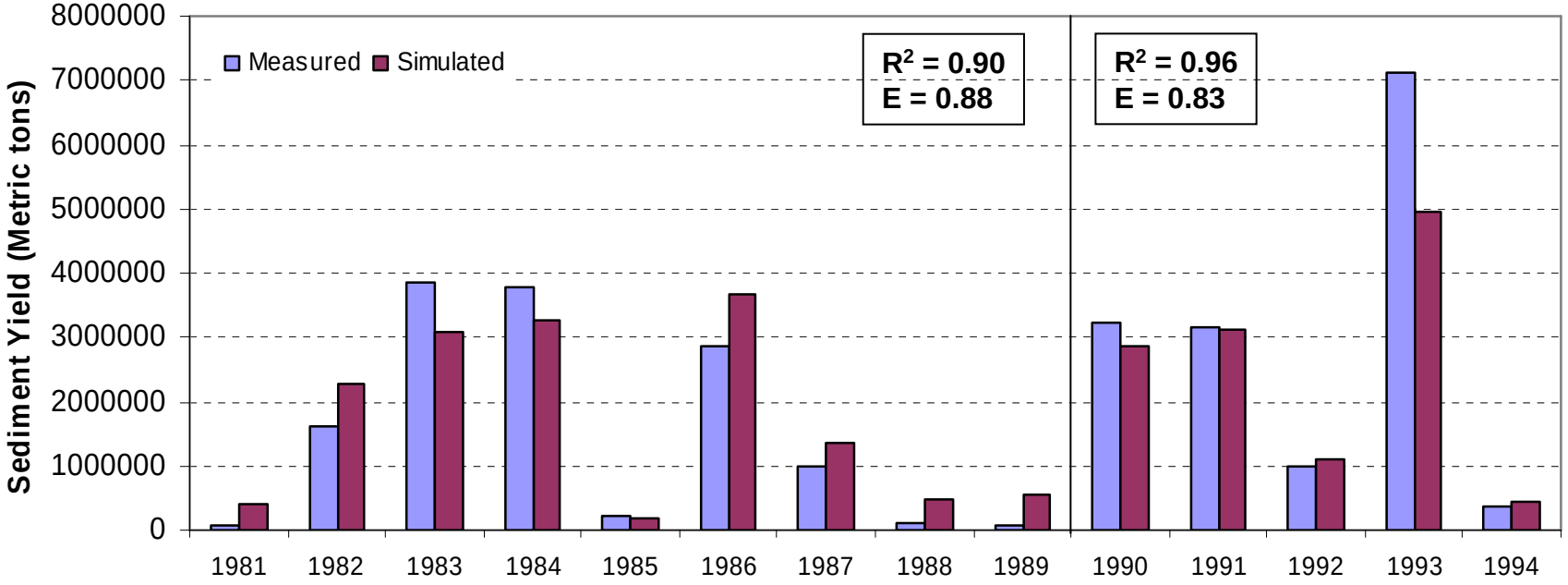
Adapted from: Zucker, L.A. and L.C. Brown (eds.). 1998. Agricultural Drainage: Water Quality Impacts and Subsurface Drainage Studies in the Midwest. Ohio State University Extension Bulletin 871. The Ohio State University.

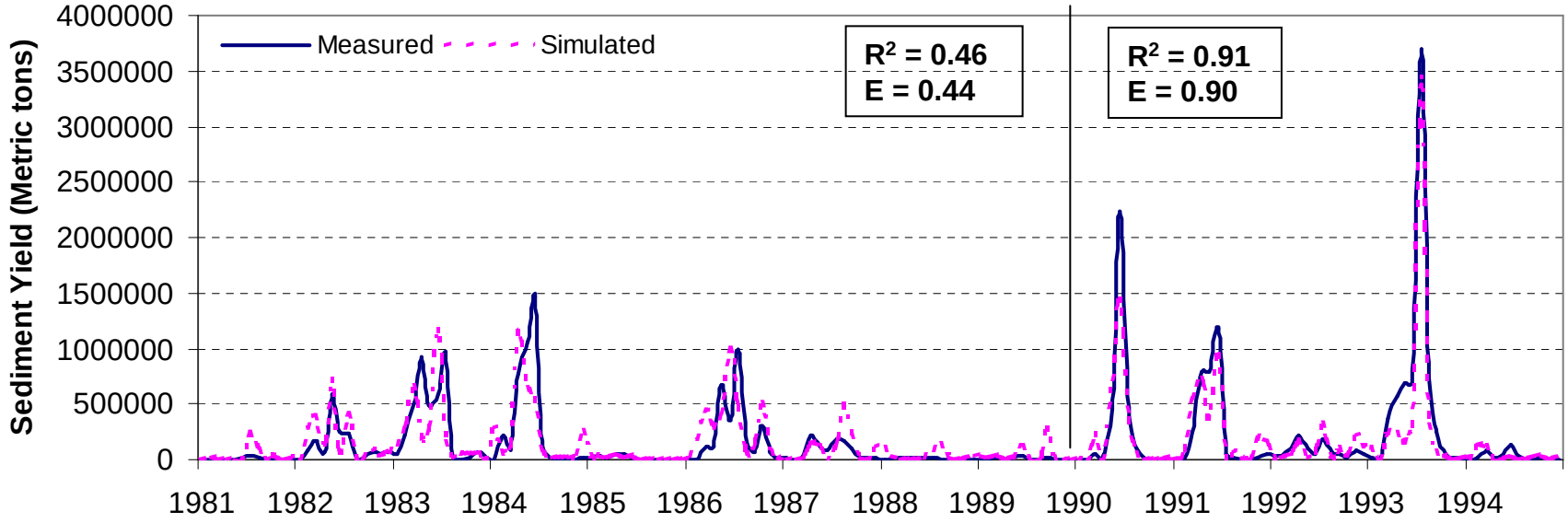
Streamflow Results for Raccoon River Watershed



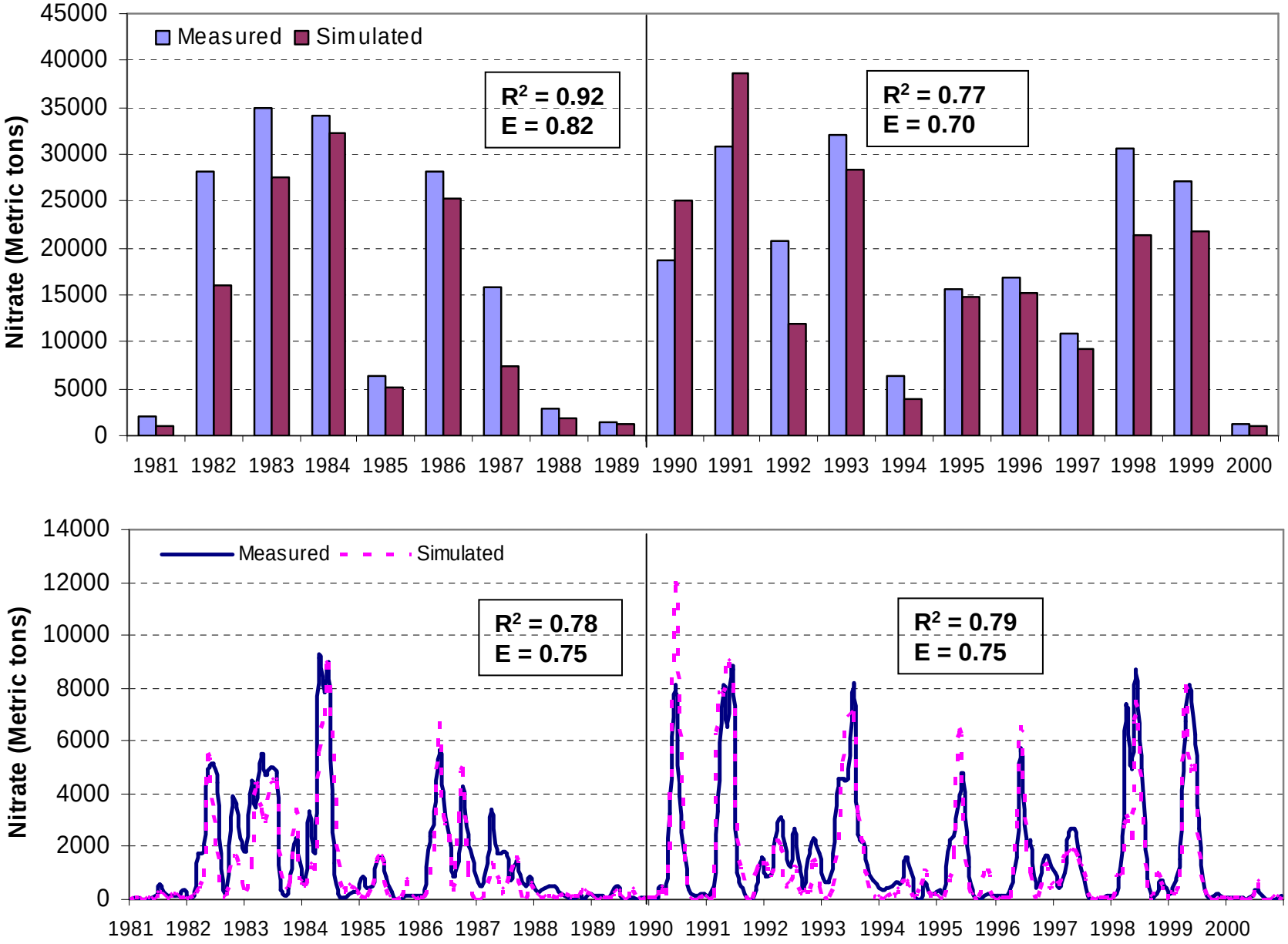


Sediment Results for Raccoon River Watershed





Nitrate Results for Raccoon River Watershed



Ok, Let's Fix Iowa's Water Quality Problems

- IDNR's original concept:

  - iterative simulations until water quality targets met

  …. slight problem with this ….

  – no one knew what those targets should be

- Plan B: simulate aggregate impacts of expanding conservation practices using a simple algorithm

Conservation Practice Scenarios

- Core set of five practices: land set aside, terraces, contouring, grassed waterways, and conservation tillage

  - land set aside: first look at NRI distance to stream; mainly determined as a function of the NRI Erosion Index (EI)

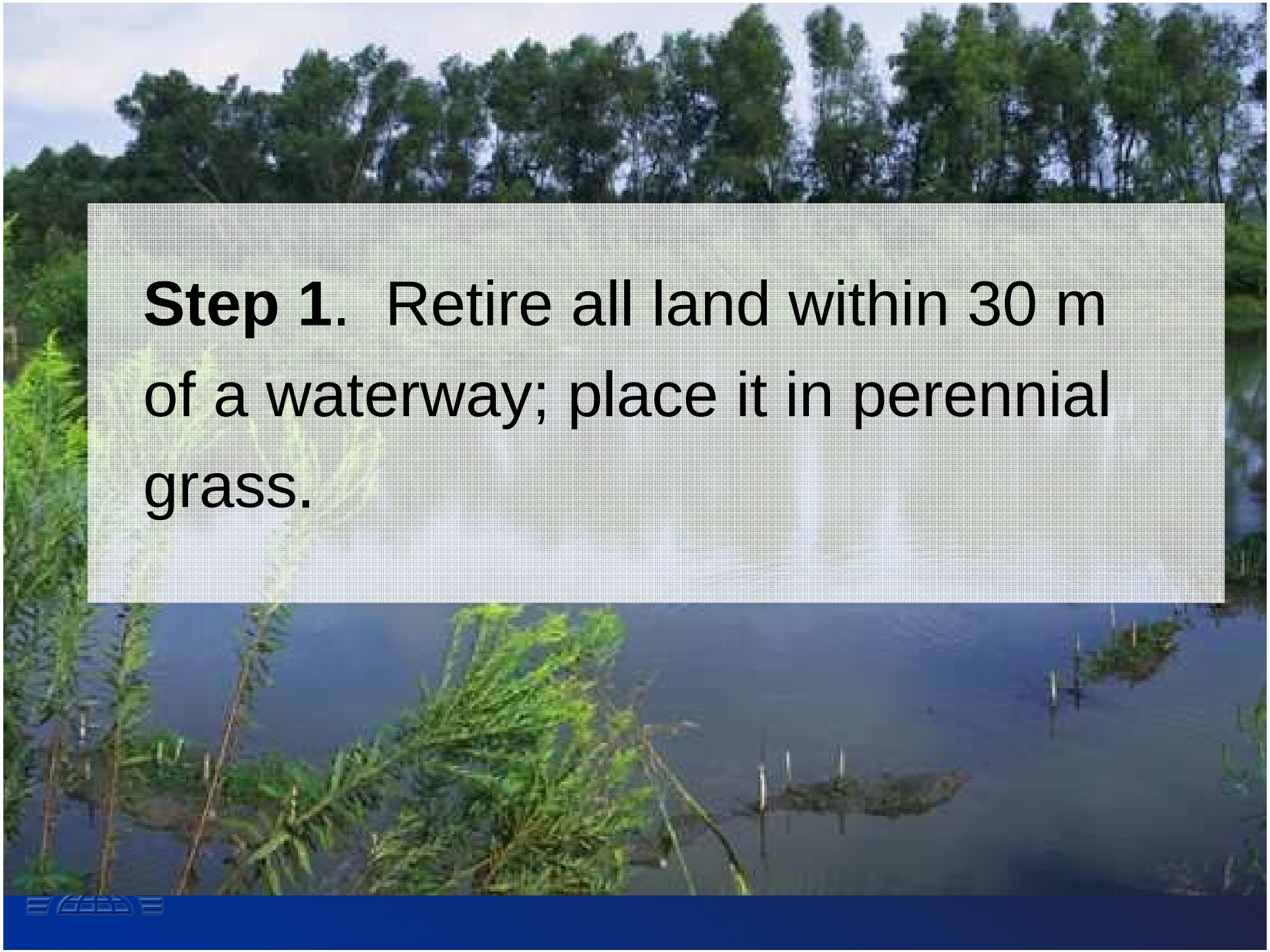
  - other practices: function of % slope

- Scenario 1: all practices simulated simultaneously

- Scenario 2: same as scenario 1 except that a 10% fertilizer reduction was added

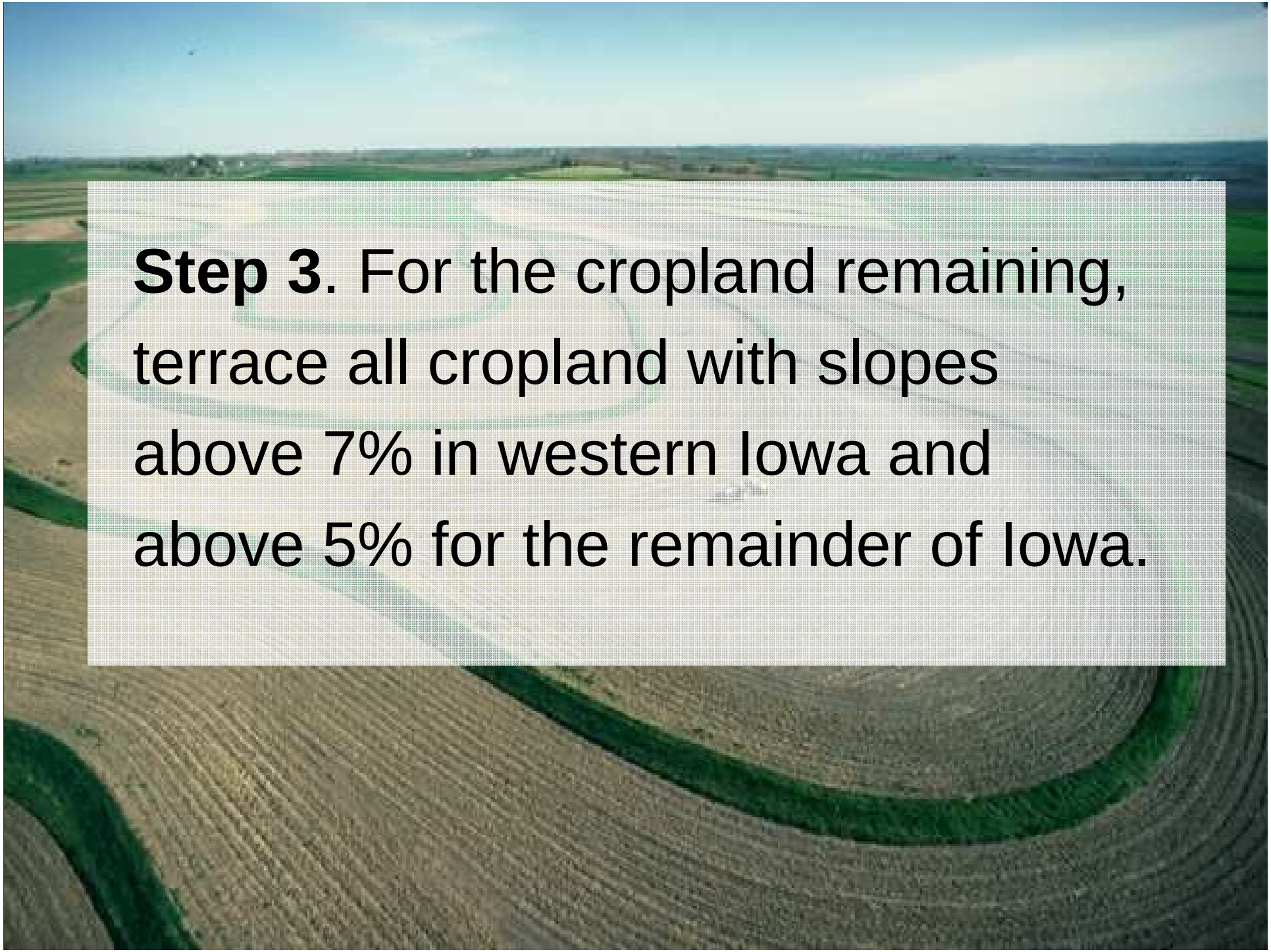
  - did not account for manure applications or more rigorous fertilizer management scenarios

- Also ignored other options such as riparian zones, in-field buffers, and wetlands



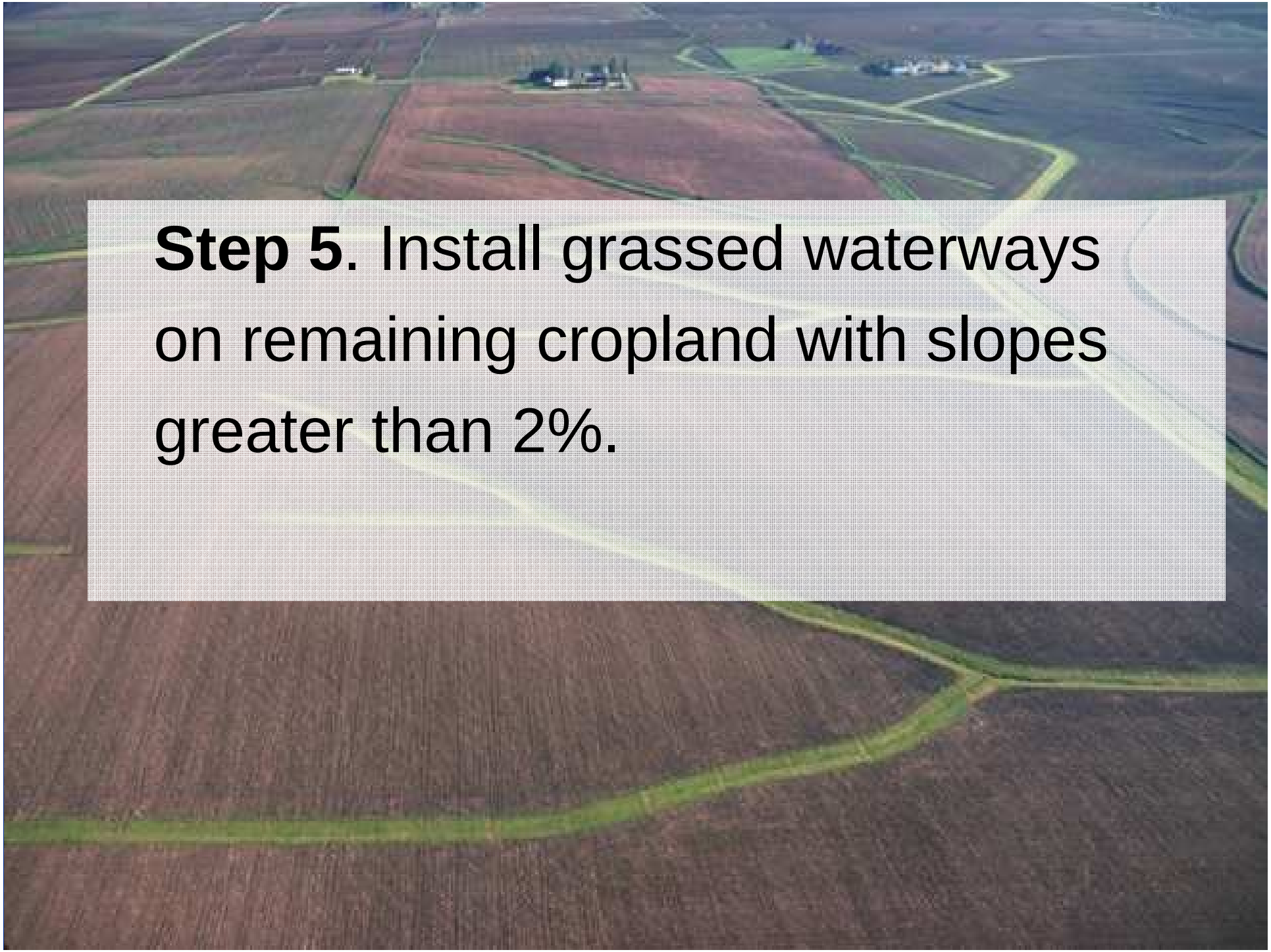
Step 1. Retire all land within 30 m of a waterway; place it in perennial grass.

Step 2. Retire additional land to until 10% of all cropland in the state is in land set aside, based the NRI EI (again in perennial grass).



Step 3. For the cropland remaining, terrace all cropland with slopes above 7% in western Iowa and above 5% for the remainder of Iowa.

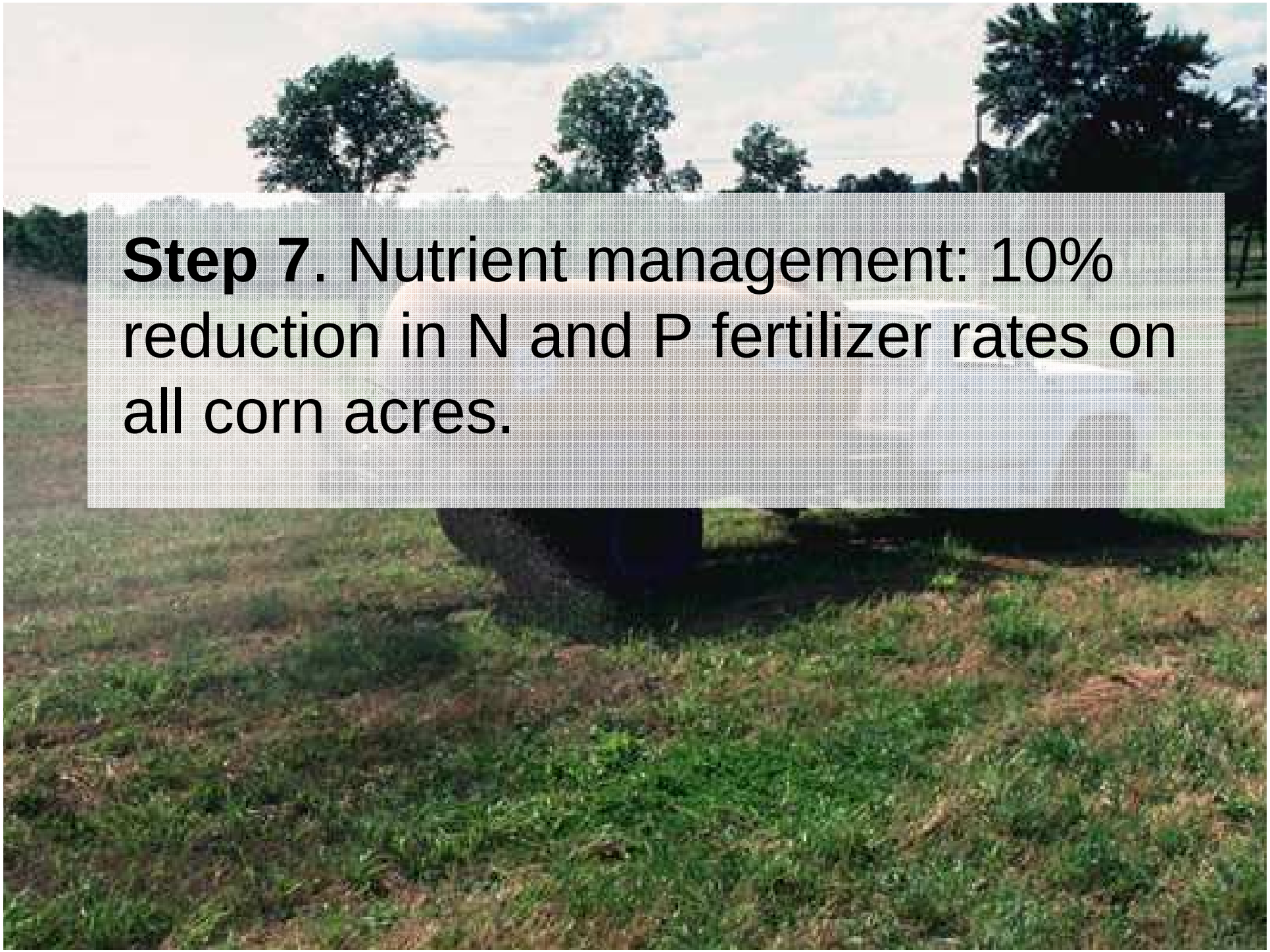
Step 4. For all remaining cropland, place acreage with slopes above 4% in contour farming.



Step 5. Install grassed waterways on remaining cropland with slopes greater than 2%.

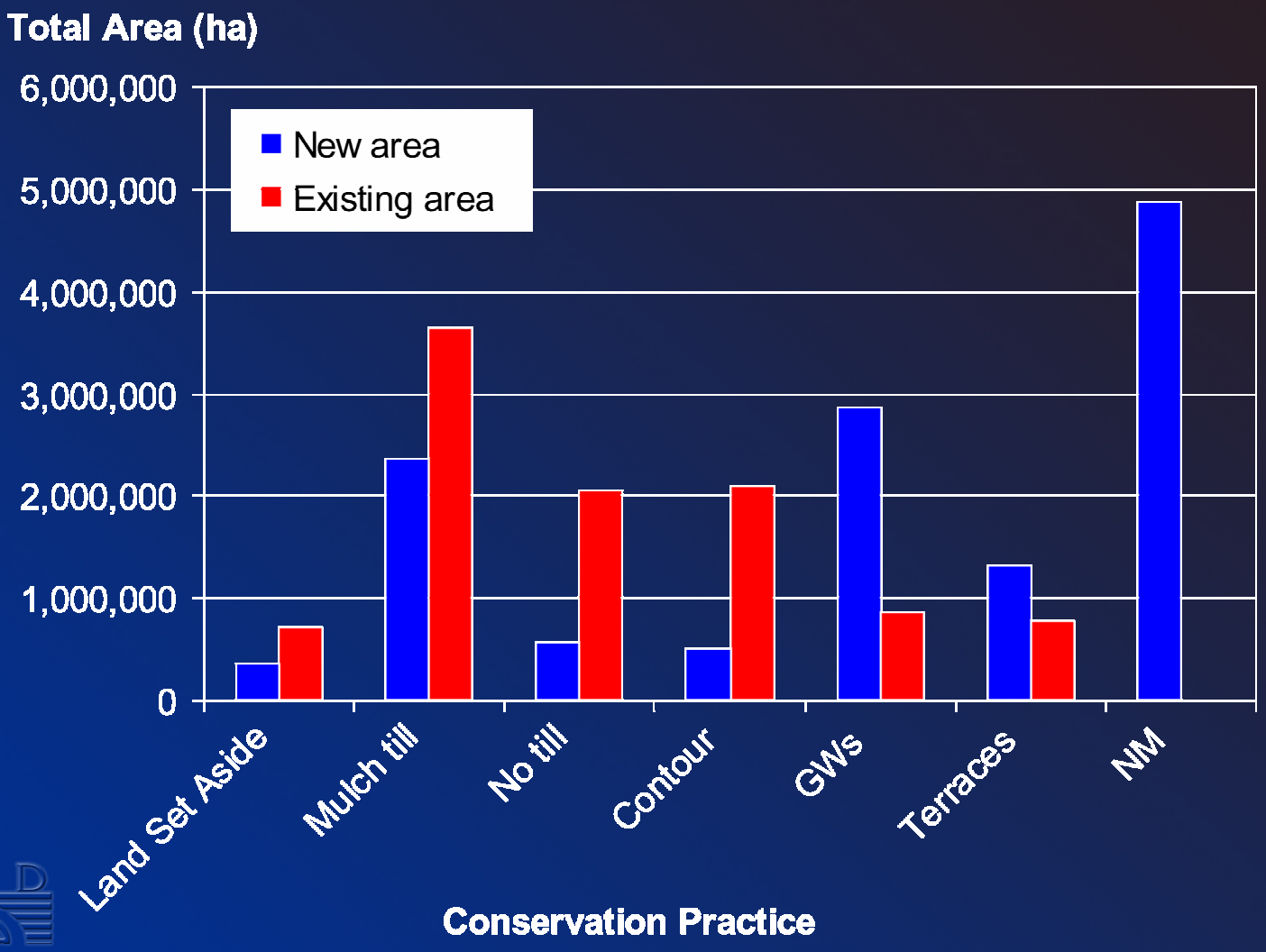
Step 6. For all cropland with slopes ≥ 2% (and not in land set aside), place 20% in no till and 80% in mulch tillage.

- mulch tillage ≥ 30% residue
- no till ≥ 60% residue



Step 7. Nutrient management: 10% reduction in N and P fertilizer rates on all corn acres.

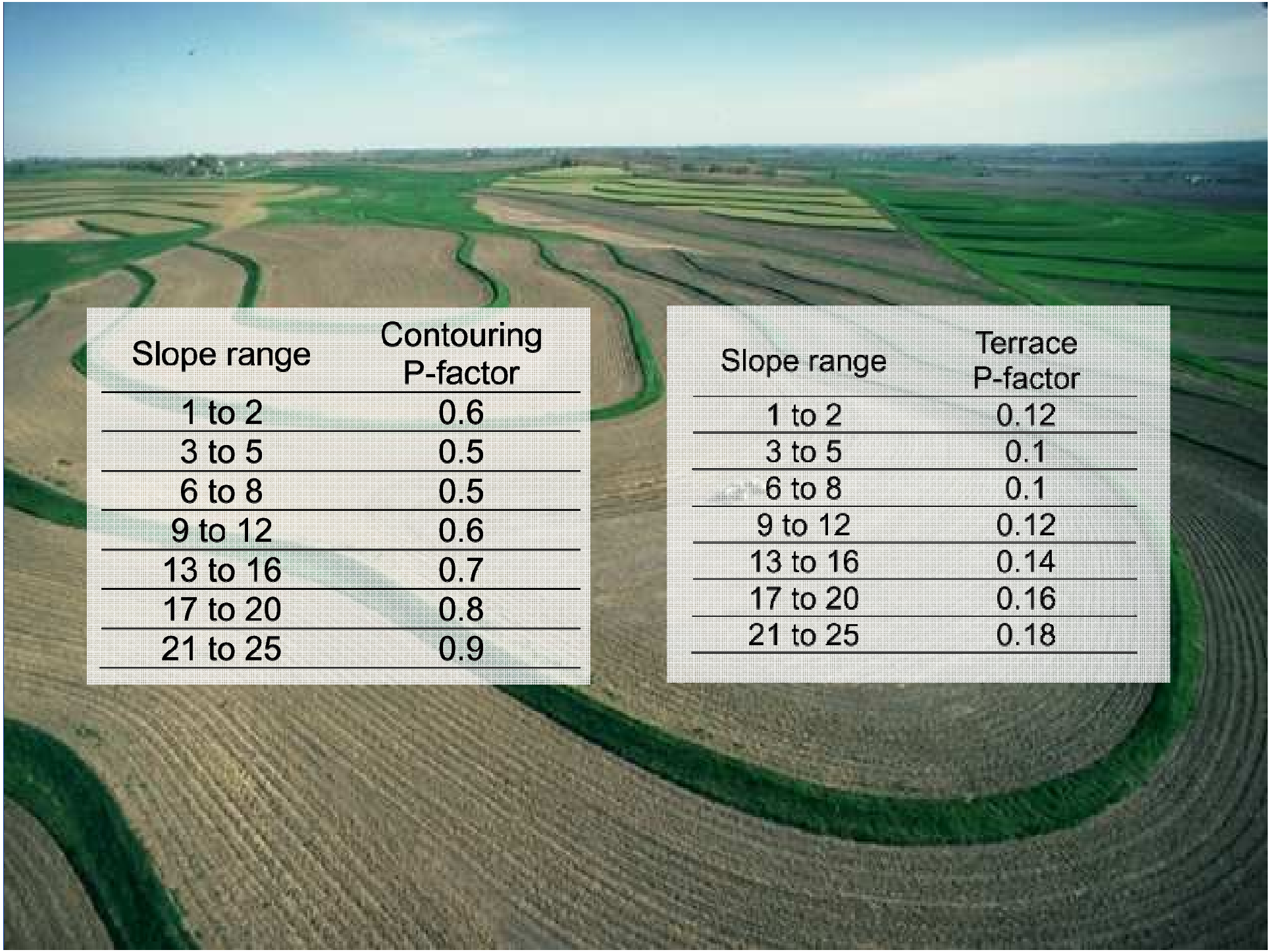
Existing (Baseline) and New Areas of each Conservation Practice for all of Iowa



SWAT Scenario Simulations

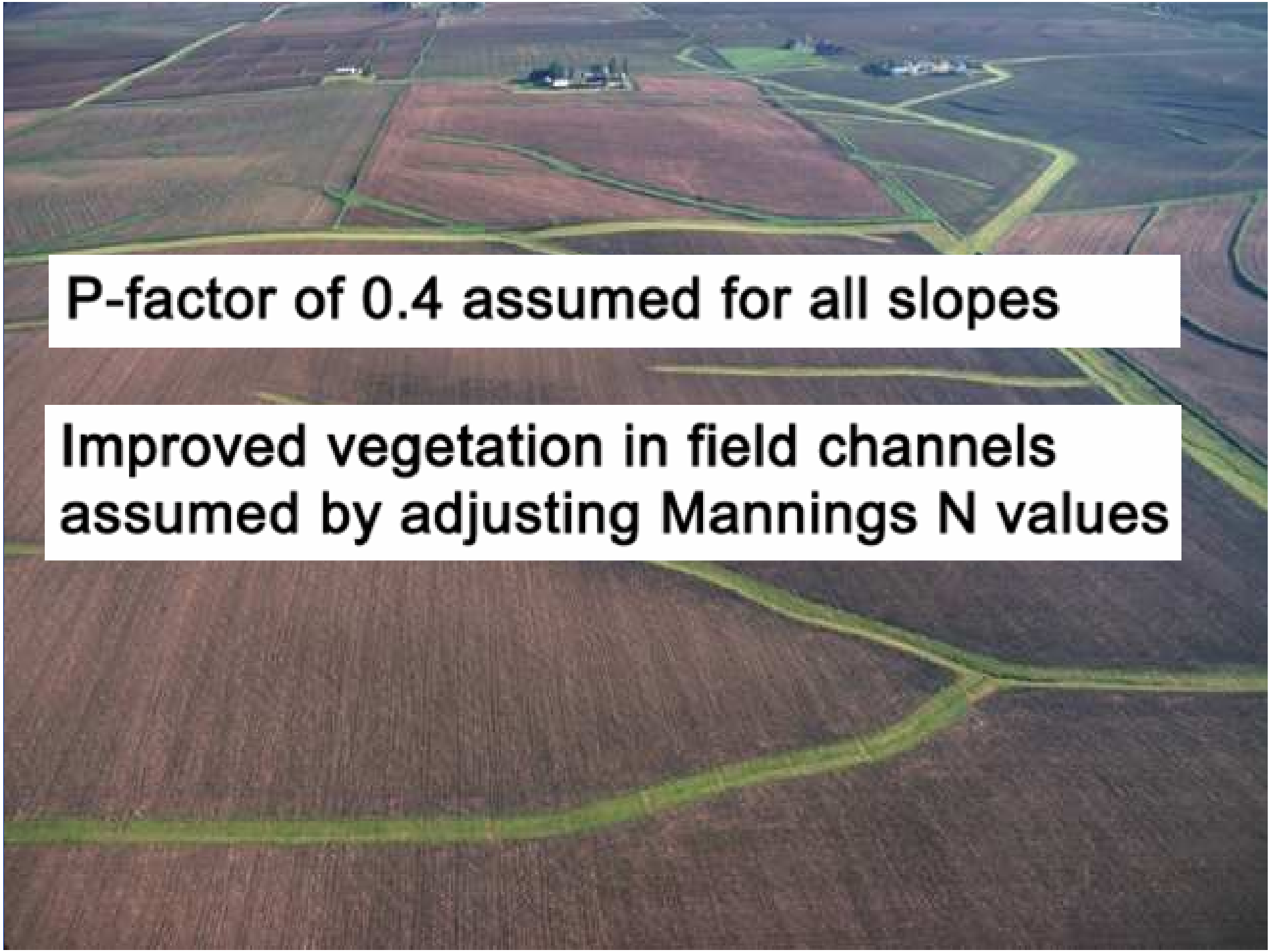
- **Two simulation sets for scenarios 1 and 2**
- **20-year simulations using 1981-2000 climate data**
- **Results: % changes in average annual values relative to the baseline**

  -indicators: sediment, total P, total N, nitrate



Slope range	Contouring P-factor
1 to 2	0.6
3 to 5	0.5
6 to 8	0.5
9 to 12	0.6
13 to 16	0.7
17 to 20	0.8
21 to 25	0.9

Slope range	Terrace P-factor
1 to 2	0.12
3 to 5	0.1
6 to 8	0.1
9 to 12	0.12
13 to 16	0.14
17 to 20	0.16
21 to 25	0.18


P-factor of 0.4 assumed for all slopes
Improved vegetation in field channels assumed by adjusting Mannings N values

% Reductions in Sediment & Total P

(Same impact for both scenarios)

Watershed	Sediment	Total P (scenario 1)	Total P (scenario 2)
Floyd	30	51	52
Monona	11	41	42
Little Sioux	6	48	49
Boyer	35	53	53
Nishnabotna	43	51	52
Nodaway	45	45	45
Des Moines	10	37	37
Skunk	63	51	51
Iowa	14	47	48
Wapsipinicon	64	49	50
Maquoketa	47	55	56
Turkey	65	58	59
Upper Iowa	50	27	28

% Reductions in Nitrate

Watershed	Scenario 1	Scenario 2
Floyd	-1	13
Monona	2	17
Little Sioux	2	11
Boyer	4	16
Nishnabotna	13	20
Nodaway	6	11
Des Moines	-5	6
Skunk	5	13
Iowa	-5	6
Wapsipinicon	1	9
Maquoketa	-6	9
Turkey	-3	10
Upper Iowa	1	10

% Reductions in Total N

Watershed	Scenario 1	Scenario 2
Floyd	9	20
Monona	8	20
Little Sioux	7	15
Boyer	19	27
Nishnabotna	25	30
Nodaway	17	22
Des Moines	14	20
Skunk	12	19
Iowa	23	29
Wapsipinicon	6	14
Maquoketa	6	19
Turkey	8	19
Upper Iowa	10	17

Program Cost Estimates

- IDNR desired that costs be expressed as “program costs” in terms of net present value

  -annualized costs also calculated (not shown)

- Phased-in over 10-year period

  - considered a reasonable representation of an actual program

- Costs computed for both existing and new practices (unlikely existing would be included)

Costs of Practices

- Land set aside were estimated based on typical land rental costs in Iowa (simulated estimates)
- Conservation tillage: fixed costs - $24.7/ha for no till and $49.4/ha for mulch till
- Nutrient management: assumed that producers incur one-time cost of $37/ha

  - also assumed that 10% N reduction would have a negligible effect on corn yields